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*Published in:*  
Medicina

*DOI:*  
[10.3390/medicina55040097](https://doi.org/10.3390/medicina55040097)

Published: 08/04/2019

*Document Version*  
Peer reviewed version

[Link to publication on the UWS Academic Portal](#)

#### *Citation for published version (APA):*

Yu, C., Shao, S., Awrejcewicz, J., Baker, J. S., & Gu, Y. (2019). Lower limb maneuver investigation of chasse steps among male elite table tennis players. *Medicina*, 55(4), [97]. <https://doi.org/10.3390/medicina55040097>

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Article

# Lower limb maneuver investigation of chasse steps among male elite table tennis players

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Received: date; Accepted: date; Published: date

**Abstract:** Table tennis has gained increased popularity globally. Biomechanical movement patterns in the lower limb have attracted extensive attention for coaches, scientists and athletes. The purpose of this study was to compare the differences between long and short chasse steps in table tennis as well as evaluating injury risk factors to the lower limb. Twelve male elite athletes performed forehand topspin strokes with long and short chasse steps in this study, respectively. Kinematics data of the lower-limb joints was measured by a Vicon motion analysis system. Electromyograms (EMG) of six lower-limb muscles were recorded using a myoelectricity system. Key findings were that the angle change rate of the ankle in the long chasse step was faster with a larger range of motion (ROM) in the coronal and transverse planes. The hip was also faster in the sagittal and transverse planes but smaller in the coronal plane compared with short chasse step. In addition, the vastus medialis (VM) was the first activated muscle in chasse step. The hip and ankle joints in the long chasse step and the knee joint in the short chasse step have a higher susceptible to potential injury, respectively. Moreover, tibialis anterior (TA), vastus medialis (VM) and gastrocnemius (GM) should be sufficiently stretched and warmed prior to playing table tennis. The results of this study may provide helpful guidance for teaching strategies and understanding of potential sport injury mechanism.

## 1. Introduction

As a sport, table tennis has become one of the most popular sports with over 300 million adherents worldwide (Zhang, 2017). Table tennis is not only a complex and asymmetric sport, but has various tactics utilizing speed and direction changes. Agile footwork is a rational movement that enables an athlete to rapidly change his/her position/direction and regulate his/her body for a particular stroke with maximal power and effect (Nikolić, Furjan-Mandić & Kondrič, 2014). In short, footwork is the foundation of table tennis techniques (Yin & Qu, 2013). Due to comparison of the shot characteristics between Asian and European top-level table tennis players, Malagoli Lanzoni et al. (2014) found that the performance of strokes and footwork in Asians was quick, efficient and frequent compared with Europeans. According to a previous report, the chasse step is considered as one of the most frequently used attacking footwork movement patterns with a frequency of 15.2% in competitions (Malagoli Lanzoni, Lobietti & Merni, 2007). The more specialized development of table tennis, the frequency of utilization of chasse step probably higher. Based on the positions of the balls landing on the table, athletes should perform different movement distance (long- and short chasse step). The lower limb, as the source of energy, can transfers optimum activation from the lower body segments to the upper limb via sequential movements of the kinetic chain (Fang, 2018; Elliott, 2006). Previous studies documented that a complex stroke motion required lower-limb stability and

flexibility, which could contribute to increasing the racket speed effectively (Qian et al., 2016). Considering the characteristics of performances in table tennis, athletes have to complete a series of complex spatial movements that include, acceleration, deceleration, direction change, moving quickly and balance control. All of these varied and different movement patterns help athletes generate optimum stroke production (Girard & Millet, 2009). Therefore, in order to perform the chasse step efficiently in table tennis, athletes and coaches should pay more attention to its characteristics and mechanisms. More interesting are the kinematics of the chasse step patterns in athletes' lower limbs, and whether this motion contributes to the risk of sport injuries. Also of interest is how the activation sequence of the muscles in the body segment provide movement.

During a complex motion, body segments must be coordinated in a perfect sequence that is defined as the "kinematic chain" (Elliott & Kilderry, 1983; Kibler & Van Der Meer, 2001; Girard, Micallef & Millet, 2005). This may contribute to generating more power and better control when stroking back the balls with chasse steps positioning based on the different landing positions of the ball on the table. After researched the angular kinematics between cross-court and long-line shots during table tennis forehand top spin, Malagoli Lanzoni et al. (2018) reported that the powerful torsion of the trunk would contribute to increase the development of speed during racquet swing and occur the maximum speed of the racket at the ball-racket impact moment. Iino and Kojima (2009) showed that racket speed was not only dictated by skill level, but more importantly by the lower trunk axial rotation movement in table tennis. Therefore, as the origin of the kinematic chain, lower limb drive can significantly affect the swing quality in racket sports (Elliott, 2006; Girard et al., 2005; Seeley, Funk, Denning, Hager & Hopkins, 2011). Iino and Kojima (2001) stressed that the hip motion played a key role in trunk rotation, and Qian et al. (2016) reported that the hip joint was vital to power generation and transmission in lower limb drive. Seeley et al. (2011) stated that the hip and ankle were important factors in the kinematic chain. Moreover, the characteristics of the kinematic chain reveal that maximum velocities gradually transfer from the knee to the racquet (Girard et al., 2005; Elliott, Marshall & Noffal, 1995; Van Gheluwe & Hebbelinck, 1986). These studies were consistent in the view that completing a good table tennis technique requires optimum activation of all the links in the kinematic chain.

Risk factors for injury exist in all sports. Previous studies showed that the injury rate of the lower limb was higher than the upper extremity, with ranges from 39% to 59% of the total presented injuries (lower limb, upper extremity and the central core injuries) (Hutchinson et al., 1995; Kibler & Safran, 2004). Kibler (1995a, 1995b) found that any disruption of the kinematic chain could induce increased loading of other joints in the sequential movements of body segments. Lam et al. (2018) investigated the footwork effects on lower-limb kinematics and kinetics, which would provide useful guidance for training protocol and further understanding of injury mechanism. Generally, stretching is widely taken to be the effective warm-up strategy before strenuous exercise (Shehab et al., 2006; Herman et al., 2012). Previous studies showed that electromyography (EMG) can be used to detect the patterns of muscle activation in the upper and lower limb in racket sports (Van Gheluwe & Hebbelinck, 1986; Anderson, 1979; Miyashita et al., 1980; Chow, Shim & Lim, 2003). Therefore, EMG measurement may be used to identify what muscles play primary roles in table tennis chasse step movement patterns. This knowledge can improve performance characteristics and reduce the possibility of muscle strain. This may then inform future prevention strategies for the pre-exercise warm-up. According to previous studies, females might have different psychological attitudes and different perceptions compared to their male counterparts (Brody, 1993). This could influence performance outcomes. However, this study only paid attention to the chasse step based on the position of the balls landing on the table.

The aim of the study was to investigate the biomechanics between long and short chasse steps in table tennis and evaluate any potential injury risk factors for the lower limb. It was hypothesized that a short chasse step would take a smaller amount of time than the long chasse step during the chasse step movement. The long chasse step would show larger ROM and faster angle change rate compared with short chasse step. It was also hypothesized that the Vastus medialis muscle may be the first activated muscle during chasse step.

## 99 2. Methods

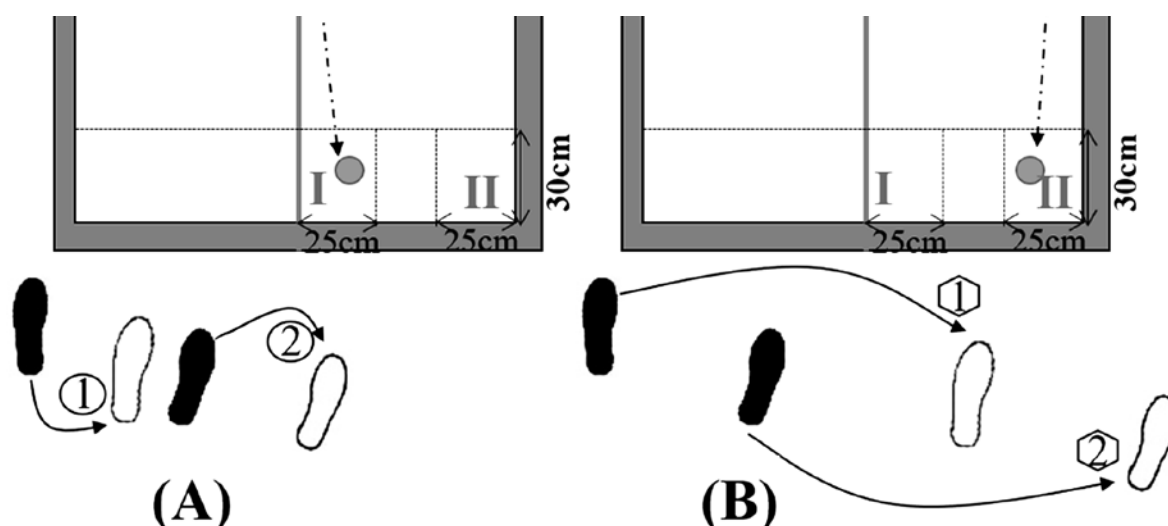
### 100 2.1. Participants

101 Twelve elite male national level players (age:  $20.64 \pm 1.42$  years; height:  $1.74 \pm 0.03$  m; **body mass:**  
102  $67.73 \pm 3.31$  kg and training experience:  $12.7 \pm 1.5$  years) participated in this study. All participants  
103 were free from any previous lower limb injuries and surgeries or foot diseases. This study was  
104 approved by the Ethics Committee of Ningbo University (No. 2016FS021) and the participants were  
105 informed of experimental procedures and requirements. Written consent was obtained before  
106 experimental data collection.

107 In order to determine the dominant lower limb, the ball-kick test was used in this study (Zakas,  
108 2006). In this test, each participant was asked to kick a football with arbitrary power and maximal  
109 accuracy through a set of obstacles placed 1 m apart and 10 m from the participants, the supporting  
110 leg was regarded as a non-dominant limb and the other side was the dominant limb when kicking  
111 the football. In addition, this study followed the suggestions of Peters and Murphy (1992) to  
112 determine the handedness, and selected the right-handed athletes as the participants.

### 113 2.2. Experimental Setup and Data Processing

114 Testing sessions were conducted in the Ningbo University table tennis training center. A table  
115 tennis machine (DOUBLE FISH, CN) was placed 1.2 m away from the opponent's court and  
116 presented topspin balls to the participants. The velocity, projecting angle and the frequency were  
117 consistent for all serving balls (Butterfly, JPN). Before testing, the participants were given a  
118 standardized warm-up of 20 min within the experimental environment. All participants were  
119 informed of the test purposes and procedures, and used their own racquets (backplane: butterfly;  
120 forehand rubber: hurricane 3; backhand : tenergy 05). During testing, the participant firstly  
121 performed forehand returns to the service 2~4 times at the left of table, then stroked A or B region  
122 balls (Figure 1) using a forehand loop with chasse step recorded by a Vicon motion analysis system,  
123 separately. Participants stroked at each region (A or B) until 20 acceptable motions were  
124 accomplished. An eight-camera Vicon motion analysis system (Oxford Metrics Ltd, Oxford, UK) was  
125 used to capture the lower-limb kinematic data with a frequency of 200 Hz, while sixteen standard  
126 markers were adhered at the anterior-superior iliac spine, posterior-superior iliac spine, lateral mid-  
127 thigh, lateral knee, lateral mid-shank, lateral malleolus, second metatarsal head and calcaneus of the  
128 lower limb. An 8-channel surface EMG (ME6000, Mega Electronics, Finland) was used to collect  
129 biceps femoris (BF), gluteus maximus (GM), rectus femoris (RF), gastrocnemius (GN), vastus medialis  
130 (VM) and tibialis anterior (TA) muscles' surface EMG signals with a sampling frequency of 1000 Hz.  
131 The surface of the skin was prepared by cleaning and shaving, using an isopropyl alcoholic swab  
132 before wearing the myoelectric pads. An electrical muscle stimulator was used to locate each muscle's  
133 belly. The different equipment did not affect hitting actions of the players.



**Figure 1. Short and long chasse steps and table designs.** I and II are the different landing positions of the balls, respectively. A and B mean short and long chasse steps, respectively. ①, ② and ①, ② are the footwork orders for chasse steps.

### 2.3. Data Recording and Statistics Analysis

The whole motion phase was collected, and two key phases were identified for subsequent joint angle analysis. The chasse step referred to two certain events, which include takeoff instant (TI) of the dominant foot on the initial position and the backward-end (BE) moment on the completed position. Each participant's sagittal, coronal and horizontal ROM, and angle change rate of the lower limb joints were recorded during one entire cycle. Joint angles in three planes were time-normalized to 100 data points for subsequent analysis.

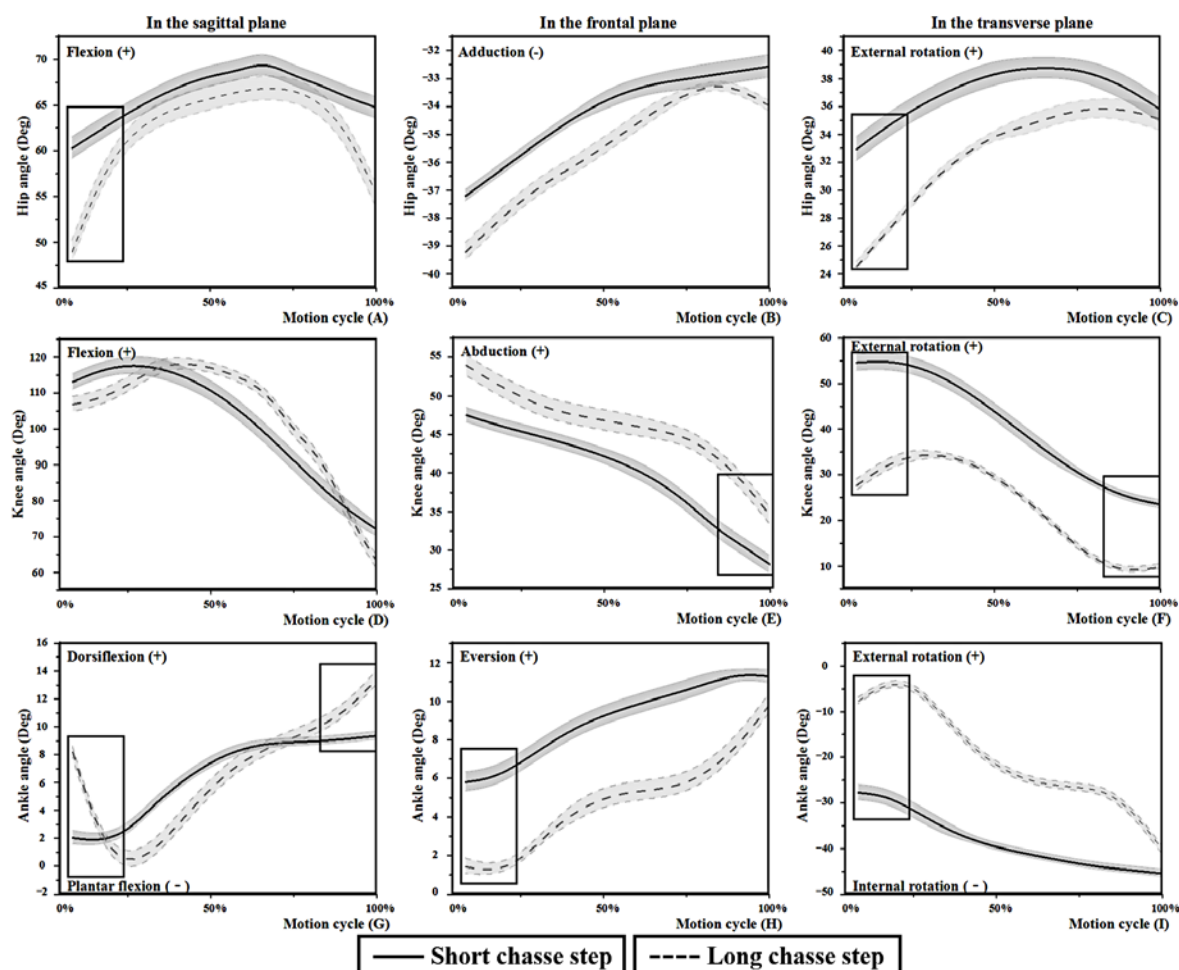
In order to obtain maximum EMG levels, each participant performed 10 chasse steps with comparable efforts. Firstly, EMGs were band-pass filtered (high-pass 20 Hz, low-pass 450 Hz) and full-wave rectified, then the EMG signals using root-mean-square (RMS) amplitude with a 40-s moving window were used to represent muscle activation. For each muscle, onset of muscle activation was defined as a rise in the EMG signal amplitude greater than maximum EMG levels of 25% during one chasse step, lasting longer than 50 ms (Li & Caldwell, 1998). SPSS version 17.0 software (SPSS Inc., Clhicago, USA) was used for statistical analysis. An initial Shapiro-Wilk test confirmed that the data was normally distributed. To examine the differences between the two movements, a paired *t*-test was taken for each variable including the joint angles at TI and BE moments, and the time of the entire motion and joints ROM. One-way ANOVA was used to analyze the differences of angle change rate at three planes during the long stroke. The significance level was set at  $p < 0.05$ . According to the equations previous described, Cohen's *d* was used to compare the differences in the average of the two groups, and is often represented by the effect size (Cohen, 1988). Effect size (ES) is evaluated as trivial ( $\geq 0.19$ ), small ( $\geq 0.2$  and  $\leq 0.49$ ), medium ( $\geq 0.50$  and  $\leq 0.79$ ) and large ( $\geq 0.80$ ), respectively (Cohen, 1988). The statistical methods to calculate RMS amplitude were as follows:

$$\sqrt{\frac{1}{N} \sum_{i=1}^N EMG(i)^2} \quad (\text{Gentili, Papaxanthis \& Pozzo, 2006}) \quad (1)$$

In this formula: *N* represents the data length; *i* represents the amplitude.

### 3. Results

The time for performing the two chasse steps were  $0.52 \pm 0.02$  s and  $0.59 \pm 0.01$  s ( $p < 0.001$ ) for the short and long strokes, respectively. In figure 2, the differences of joint angles between long and short chasse steps in three planes were generally comparable. As table 1 shows, the ROM of hip joint for the long chasse step was larger in the sagittal and transverse planes. The ROM of the ankle showed also larger differences in the coronal and transverse planes but the ROM of knee was smaller in the coronal plane compared with the short chasse step. In figure 2, the peak joint angles are shown and mostly occurred at the TI or the BE.



**Figure 2.** The differences in hip (A-C), knee (D-F) and ankle (G-I) angles during one motion cycle in three planes. “□” means  $P < 0.05$  between the two chasse steps at key event.

**Table 1.** Mean  $\pm$  standard deviations (Mean  $\pm$  SD), standard error of measurement (SEM), 95% confidence intervals (CI), effect sizes (ES) for the lower-limb joints ROM of the motion between long and short chasse steps.

Short or long chasse steps			Mean $\pm$ SD	SEM	CI	ES
Hip						
X	Short		$9.57 \pm 1.30$	0.38	(8.74, 10.40)	0.83
	Long		$15.11 \pm 2.34^*$	0.68	(13.62, 16.60)	
Y	Short		$4.91 \pm 1.26$	0.36	(4.11, 5.71)	0.31
	Long		$4.12 \pm 1.17$	0.34	(3.38, 4.86)	
Z	Short		$4.70 \pm 1.06$	0.31	(4.03, 5.38)	0.91
	Long		$11.08 \pm 1.82^*$	0.52	(9.92, 12.23)	
Knee						
X	Short		$42.23 \pm 1.60$	0.46	(41.21, 43.24)	0.20
	Long		$42.87 \pm 1.60$	0.46	(41.85, 43.88)	



Ankle	Y	Short	20.70 ± 1.67	0.48	(19.64, 21.77)	0.83
		Long	16.22 ± 1.27*	0.37	(15.41, 17.03)	
	Z	Short	26.00 ± 1.37	0.40	(25.13, 26.87)	0.22
		Long	25.39 ± 1.39	0.40	(24.51, 26.27)	
	X	Short	7.66 ± 1.11	0.32	(6.95, 8.36)	0.06
		Long	7.10 ± 0.71	0.21	(6.64, 7.55)	
	Y	Short	3.82 ± 1.16	0.34	(3.08, 4.56)	0.95
		Long	10.00 ± 0.80*	0.23	(9.49, 10.51)	
	Z	Short	14.11 ± 3.83	1.12	(11.68, 16.55)	0.94
		Long	34.37 ± 3.22*	0.93	(32.32, 36.42)	

x = the sagittal plane; y = the coronal plane; z = the transverse plane. \* shows  $p < 0.05$  in the hip, knee and ankle.

Significant differences of key events were found in three planes between long and short chasse steps, particularly at the TI moment (Table 2). Compared to the short chasse step, the long chasse step showed smaller hip flexion and external rotation, larger ankle dorsiflexion but smaller eversion and internal rotation as well as smaller knee external rotation at the TI moment. Moreover, differences for BE moment were found in the knee and ankle joints. The long chasse step showed larger knee abduction and ankle dorsiflexion but smaller knee external rotation than the short chasse step.

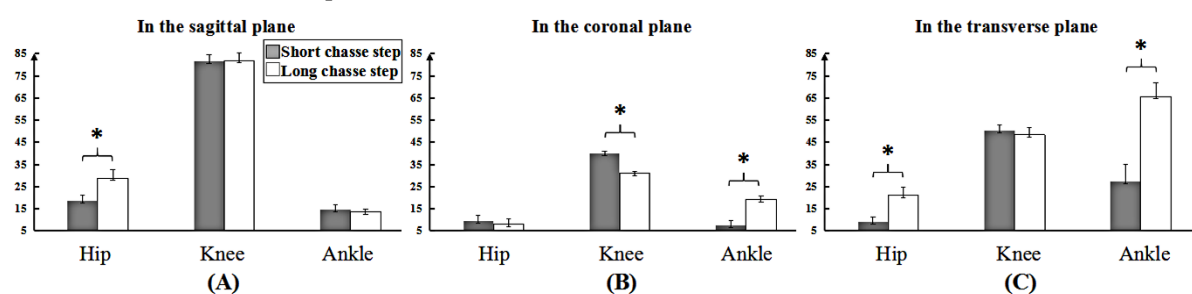
**Table 2.** Mean ± standard deviations (Mean ± SD), standard error of measurement (SEM), 95% confidence intervals (CI), effect sizes (ES) for the comparison of joint angles in two key moments in three planes between short and long chasse steps.

Short chasse step				Long chasse step			
	Mean ± SD	SEM	CI	Mean ± SD	SEM	CI	ES
Hip	X 60.16 ± 2.42	0.70	(58.62, 61.70)	48.85 ± 3.22*	0.93	(46.80, 50.89)	0.89
	Y -37.78 ± 0.94	0.27	(-38.38, -37.18)	-38.30 ± 1.39	0.40	(-39.18, -37.41)	0.21
	Z 33.01 ± 1.57	0.45	(32.02, 34.01)	24.53 ± 0.36*	0.10	(24.30, 24.76)	0.97
Knee	X 109.79 ± 3.38	0.97	(107.65, 111.94)	107.95 ± 1.42	0.41	(107.05, 108.86)	0.33
	Y 49.96 ± 2.00	0.58	(48.69, 51.23)	51.08 ± 2.04	0.59	(49.78, 52.38)	0.27
	Z 54.15 ± 1.75	0.51	(53.04, 55.27)	29.26 ± 1.77*	0.51	(28.13, 30.39)	0.99
Ankle	X 2.06 ± 1.31	0.38	(1.23, 2.89)	8.21 ± 1.07*	0.31	(7.53, 8.89)	0.93
	Y 5.81 ± 1.02	0.29	(5.16, 6.46)	1.48 ± 0.75*	0.22	(1.00, 1.96)	0.92

	Z	$-27.10 \pm 2.43$	0.70	(-28.64, -25.56)	$-11.72 \pm 1.90^*$	0.55	(-12.92, -10.51)	0.96
	X	$64.45 \pm 2.82$	0.81	(62.66, 66.24)	$55.14 \pm 3.26^*$	0.94	(53.07, 57.20)	0.84
	Y	$-32.86 \pm 1.49$	0.43	(-33.81, -31.92)	$-33.72 \pm 2.03$	0.59	(-35.01, -32.43)	0.23
Hip								
	Z	$35.33 \pm 1.59$	0.46	(34.32, 36.34)	$35.60 \pm 2.02$	0.58	(34.32, 36.88)	0.07
	X	$69.24 \pm 1.85$	0.53	(68.06, 70.41)	$69.08 \pm 2.13$	0.61	(67.73, 70.44)	0.04
	Y	$29.25 \pm 1.88$	0.54	(28.06, 30.45)	$34.86 \pm 1.45^*$	0.42	(33.94, 35.78)	0.86
Knee								
BE	Z	$28.77 \pm 1.95$	0.56	(27.54, 30.00)	$9.86 \pm 0.65^*$	0.19	(9.45, 10.27)	0.99
	X	$9.72 \pm 0.68$	0.20	(9.29, 10.15)	$10.39 \pm 0.54^*$	0.15	(10.05, 10.73)	0.48
	Y	$9.63 \pm 0.90$	0.26	(9.06, 10.20)	$9.99 \pm 0.88$	0.26	(9.42, 10.55)	0.20
Ankle								
	Z	$-41.21 \pm 2.42$	0.70	(-42.75, -39.67)	$-40.59 \pm 3.23$	0.93	(-42.64, -38.54)	0.11

TI = takeoff instant of dominant foot; BE = backward-end. x = the sagittal plane; y = the coronal plane; z = the transverse plane. \* shows  $p < 0.05$  in the hip, knee and ankle.

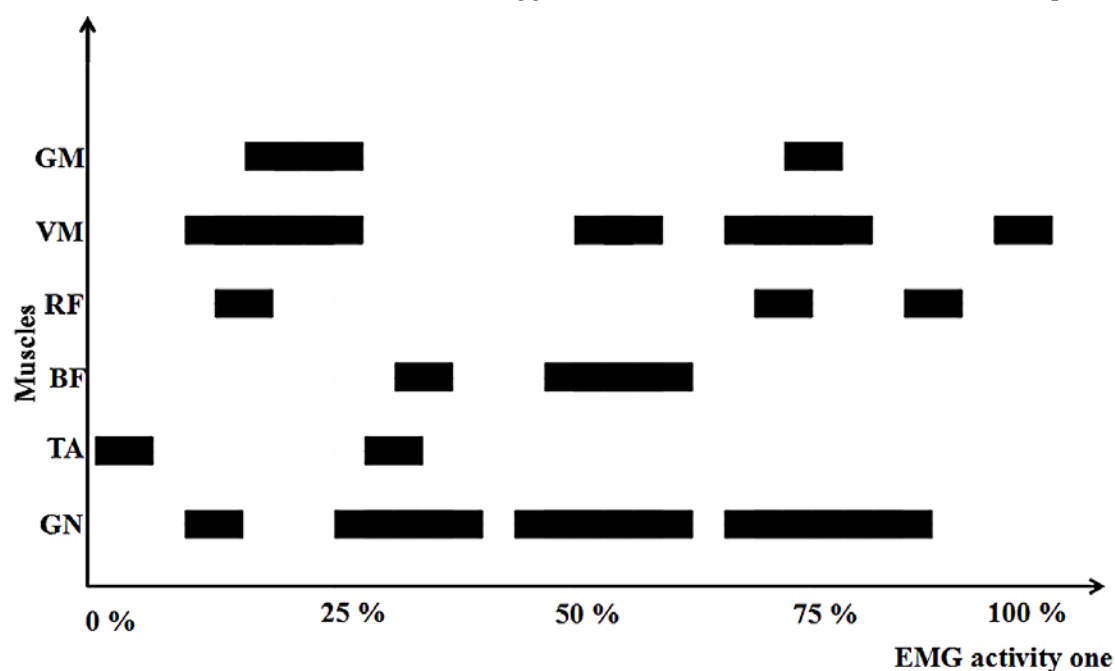
As shown in figure 3, angle change rate for the long chaise step in the hip joint was larger than the short chaise step in the sagittal and transverse planes. However, the smaller angle change rate of the knee joint for the long chaise step existed in the coronal plane, compared to the short chaise step. The angle change rate at the ankle joint for the long step showed larger than the short chaise step in the coronal and transverse planes.



**Figure 3.** The angle change rate (Deg/s) between long and short chaise steps in three planes. A, B and C shows the sagittal, coronal and transverse plane, respectively. \* shows the differences in the hip, knee and ankle joint, respectively.



Figure 4 shows the differences in activation sequence of the six muscles across an entire chasse step. Differences in muscle timing were observed. TA was activated first, followed by VM and GN and last was BF, which would offer some suggestions for coaches and athletes on warm-up strategy.



**Figure 4.** The trend of the activation sequence of the six muscles during one chasse step.

#### 4. Discussion

This study compared the biomechanics of the lower limb between long and short chasse steps in table tennis and observed the activation sequence of the selected six muscles of the lower limb. Two key technique events (takeoff instant, TI and backward-end, BE) and an entire chasse step was identified for in-depth analysis. The results showed that the short chasse step showed smaller completion time than long chasse step. Significant differences in kinematics were found for larger ROM and faster angular changing rate for the long chasse step compared with the short chasse step. There were significant differences in hip and ankle joints between the two chasse steps at the TI moment, but both of them at the BE moment showed significant differences at the knee joint. The VM muscle was the first activated muscle during one entire chasse step. The hypothesis is supported by the results that significant differences in kinematics and EMGs between long and short chasse steps exist.

For the short chasse step in the TI of the dominant foot, the hip movement exhibited larger flexion and external rotation than the long chasse step. Qian et al. (2016) emphasized that the movement of hip joint is a vital factor for energy generation and energy transference in the kinetic chain during table tennis. Combining the shorter time compared with the long chasse step, the lower center of gravity for the short chasse step would contribute to switching to the next phase efficiently. The short chasse step also showed larger knee external rotation, ankle eversion and external rotation. Previous studies demonstrated that the peak joint angles of hip flexion and larger knee external rotation during backswing could improve the ball speed in racket sports (Seeley et al., 2011; Fleisig et al., 2003). Moreover, the larger ankle eversion and external rotation would provide the short chasse step a more stable base. According to a previous study, peak pressures were higher under the medial forefoot of the dominant foot during chasse step (Yin & Qu, 2013), cooperating with larger ankle dorsiflexion of the long chasse step may be a potential factor to increase the ground reaction force that would improve technical performance. Based on the above analysis, the short chasse step exhibited a better foundation than the long chasse step, which could lead to a more flexible and fuller backswing.

In the BE moment, the long chasse step showed larger knee abduction and ankle dorsiflexion but smaller knee external rotation compared with the short chase step. Based on the theory of stretch-shortening cycle that prior stored elastic energy in the muscle-tendon stretching phase could increase concentric movement (Qian et al., 2016; Elliott, 2006; Komi & Bosco, 1978; Walshe, Wilson & Ettema, 1998), Komi and Bosco (1978) reported significant elastic energy storage for a squatting jump compared with a drop jump and counter-movement jump at the starting position. In agreement with the present findings, a greater knee external rotation at the BE moment may contribute to and facilitate stretching the internal rotator that would improve the contraction effect for forward swing. Furthermore, Elliott et al. (2003) explained that players with better lower limb inertia may transfer this to the upper limb to achieve a maximal external rotation. The larger knee abduction and ankle dorsiflexion were also found at the BE moment, which is an important factor for table tennis players to control body posture and maintain balance.

The complex structure and function of the lower-limb joints are essential for effective footwork among table tennis players. Sports injuries often occur during sport activities (training and competition), and the role of physicians goes beyond a mere diagnosis and injury treatment. Physicians are required to take part in the rehab process, training advice and they help athletes get back to practicing sport and help decrease the risk of potential injuries. An in-depth understanding of the kinematics between long and short chasse steps could allow improvements in the effectiveness of training. The results of the present study demonstrate that the long chasse step showed larger ROM compared with the short chasse step, which can infer that long chasse step possessed more flexible lower-limb joints motion, but the greater ankle internal rotation could induce the potential risk of ankle sprain (Qian et al., 2016; Fong et al., 2012) and Achilles tendinitis (Kaufman et al., 1999). Additionally, the result of the larger ROM of ankle joint eversion also had a higher risk of sport ankle sprains, as Beynnon et al. (2001) reported. The greater hip ROM can contribute to shifting weight, which can also facilitate momentum generation (Ball & Best, 2007). Moreover, there is an optimal combination of surrounding muscle, ligament, articular surfaces, tendon and joint capsule laxity (Krivickas & Feinberg, 1996), which promotes a stable center of mass shift in the long chasse step. For joint angular velocity generation, it is also necessary to understand the importance of optimizing energy transfer in the kinetic chain (Seeley et al., 2011). However, fast pivoting and landing induces lower limb injuries more easily (Zazulak et al., 2007). Compared with short chasse step in the sagittal and transverse planes, the change rate of angle at the hip joint for long chasse steps were clearly larger, while the change rate of angle at knee joint in the frontal plane was smaller. In the transverse plane, the change rate of angle at ankle joint showed larger changes for the long chasse step than short chasse step. However, lateral ankle sprains occurred at high twisting forces (Feng & Song, 2017; Kibler & Safran, 2005). Moreover, the knee is susceptible to overuse and overload injuries (Kibler & Safran, 2005). Based on the analysis of the results, the hip and ankle joints of the long chasse step and the knee joint of the short chasse step may have a higher susceptible to potential injury, respectively.

To our knowledge, the present study reported lower limb EMG and kinematics in table tennis players across the entire chasse step. According to the report of Kondrič et al. (2011), they found that the most frequent injuries in racket sports is muscle tissues from training and/or competition processes and there is a high percentage of injuries in lower-limb joints (ankle and foot in particular; 23.69% in total). They also indicated that due to the characteristics of abrupt blocking movements in playing table tennis, the percentage of hip injuries exists 5.76%. Strains and sprains were the most common type of injury in the majority of sports (Hutchinson et al., 1995). The results showed that TA was the first muscle activated during chasse step, followed by the VM and GN muscles. In the thigh areas, the adductor muscles and the hamstrings have high risks of strains, particularly during sudden direction changes (Kibler & Safran, 2005). Moreover, for the knee ROM in the coronal plane, the short chasse step was larger than the long one. The increased knee hyperextension might induce a high risk of the anterior cruciate ligament injury (Murray, 2006; Ramesh et al., 2005). Gastrocnemius muscle strains commonly occurred during repetitive and explosive accelerations of the lower limb, particularly when using sprinting or jumping movements (Kibler & Safran, 2005). In order to reduce

the incidence of muscular strains and sprains, this study suggest that warm-up for TA, VM and GN muscles may be beneficial.

However, there are some limitations that should be mentioned in this study. First of all, a small sample size may limit the external validity to some degree. Secondly, this study lacked the comparison of the relationship between skill level and gender between long and short chasse steps. Finally, the generalization and application of these findings to players from other counties may be treated with caution. This is related to the fact that the participants in this study were from China.

## 5. Conclusions

For the short chasse step, the knee may be at a higher risk of sport injury in the frontal plane. For the long chasse step, the hip in the sagittal and transverse planes, and the ankle in the transverse plane could have a higher risk for sport injury. Therefore, some pertinent protective measures should be adopted when table tennis players practice the long or short chasse steps. These may include systematic strengthening of the muscle involved in the different chasse steps. Coaches and players also should pay more attention to flexibility training for tibialis anterior, vastus medialis and gastrocnemius muscles during the pre-exercise warm-up.

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